ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

TASK 6 - DESIGN DEVELOPMENT

SUBTASKS 6.09 & 6.10 - DESIGN CRITERIA FOR WATANA AND DEVIL CANYON DEVELOPMENTS

MAY 1981

ACRES AMERICAN INCORPORATED
1000 Liberty Bank Building
Main at Court
Buffalo, New York 14202
Telephone (716) 853-7525

TABLE OF CONTENTS

Page

1.0 - GENERAL .....

2.0 - PROJECT PARAMETERS .....

3.0 - PROJECT DESIGN DATA .....
- 3.1 - Topographical Data .....
- 3.2 - Hydrological Data .....
- 3.3 - Meteorlogical Data .....

4.0 - DESIGN CRITERIA .....
- 4.1 - Civil Design .....
- 4.2 - Hydraulic Design .....
- 4.3 - Geotechnical Design .....
- 4.4 - Mechanical Design .....
- 4.5 - Electrical Design .....

5.0 - ENVIRONMENTAL RESTRICTIONS .....

Susitna Hydroelectric Project

Project Parameters and Design Criteria

1.0 - General

The following sets out the principal project parameters and the design criteria for the proposed Watana and Devil Canyon hydroelectric projects.

Much of this document is tentative at this stage as it will be subject to confirmation or revision throughout the feasibility study. It is intended that with further amendment as additional data becomes available it will form the basis for the final engineering design criteria and it is broken down into general project parameters and design criteria for the individual engineering disciplines in such a fashion as to be readily incorporated into this final criteria.

2.0 - Project Parameters

Item	Watana	Devil Canyon
River Flows		
Average flow (over 30 yrs of record)	7,860 c.f.s.	8,960 c.f.s.
Probable Maximum flood	235,000 c.f.s.	270,000 c.f.s.
Max. flood with return period of 1:10,000 yrs	155,000 c.f.s.	135,000 c.f.s (after routing through Watana)
Max. flood with return period of 1:500 yrs.	116,000 c.f.s.	--
Max. flood with return period of 1:50 yrs.	87,000 c.f.s.	42,000 c.f.s. (after routing through Watana)
Normal max. operating level	2,200' MSL	1,445' MSL
Minimum operating level	2,050' MSL	1,440' MSL
Area of reservoir at max. operating level	40,000 acres	21,000 acres

Item	Watana	Devil Canyon
Reservoir live storage	4.6×10^6 acre ft	0.75×10^6 acre ft
Reservoir full storage	10.0×10^6 acre ft	1.1×10^6 acre ft
Dam		
Type	Rockfill	Concrete arch
Crest elevation	2,225' MSL	1455' MSL
Crest length		
Height	890 ft above foundation	670 ft above foundation
Cut-off and foundation treatment	Core founded on Grout curtain & downstream drains.	Founded on rock. Grout curtain & downstream drains.
Upstream slope	1V:2.75H	-
Downstream slope	1V:2.0H	-
Crest width	80 ft	20 ft
Diversion		
Cofferdam types	Rockfill	Rockfill
Cut-off and foundation		Founded on alluvium with slurry trench to rock.
Upstream cofferdam crest elevation	1560' MSL	960' MSL
Downstream cofferdam crest elevation	1500' MSL	900' MSL
Max. pool level during construction	1555' MSL	955' MSL
Min. pool level during construction	Approx. 10 ft above crown of outlet	Approx. 10 ft above crown of outlet
Water passages	Concrete lined	Concrete lined

Item	Watana	Devil Canyon
Outlet structures	Low level structure with high head slide gates to operate under low heads.	955' MSL
Final closure	Mass concrete plugs in line with dam grout curtain.	Mass concrete plugs in line with dam grout curtain.
Releases during impounding	2000 c.f.s. min. via bypass to outlet structure	2000 c.f.s. via low level Howell Bunger valves.
Emergency Releases		
Draw down requirements	To be determined.	-
Discharges	To be determined.	-
Water passages	Concrete lined tunnels discharging into downstream diversion tunnels.	-
Outlet structures	Mid reservoir level	-
Gate chambers	Underground chambers housing wheel mounted control gates.	-
Energy dissipation	To be determined.	-
Spillway		
Design Floods	Passes p.m.f., preserving integrity of dam with no loss of life.	Passes p.m.f., preserving integrity of dam with no loss of life.
	Passes routed 1:10,000 yr. flood with no damage to structures.	Passes routed 1:10,000 yr. flod with no damage to structures.

Item	Watana	Devil Canyon
Main spillway - Capacity	Routed 1:10,000 yr flood (115,000 cfs) with 5' surcharge	-
- Control structure	Gated ogee crests.	-
- Energy Dissipation	To be determined.	-
Secondary spillway - Capacity	Not applicable.	45,000 c.f.s.
- Control Structure	-	
- Energy Dissipation	-	
Emergency spillway - Capacity	P.m.f. minus 1:10,000 yr flood	P.m.f. minus routed 1:10,000 yr flood (135,000 cfs)
- Type	Fuse plug	Fuse plug.
Power Intake		
Type	Massive concrete structure embedded in rock.	Massive concrete structure embedded in rock.
Number of intakes	4	4
Draw-off requirements	Multi-level corresponding to temperature strata.	Multi-level corresponding to temperature strata.
Gate chambers		
Drawdown	150'	Not determined.
Penstocks		
Type		Concrete lined rock tunnels with downstream steel liner.
Number of penstocks	4	4
Powerhouse		
Type	Underground	Underground
Transformer area	Separate gallery	Not determined.
Control room & administration	Surface	Not determined.
Access - Vehicle	Rock tunnel.	Rock tunnel.
- Personnel	Elevator from surface.	Not determined.

Item	Watana	Devil Canyon
Power Plant		
Type of turbines	Francis	Francis
Number and rating	4 x 270 MW	4 x 150 MW
Rated net head	680 ft	550 ft
Design Flow	5,300 cfs per unit	3630 cfs
Maximum gross head	745 ft	565 ft approx.
Maximum flow		
Type of generator	Vertical synchronous	Vertical synchronous
Rated output	310 MVA	172 MVA
Power factor	0.9	0.9
Frequency	60 HZ	60 HZ
Transformers	310 MVA 13.8-345 kv, 3-phase	To be determined 13.8-345 kv, 3-phase
Tailrace		
Water passages	2 concrete lined tunnels.	2 concrete lined tunnels.
Elevation of water passages	Below min. tail-water	Below min. tailwater
Surge Number of penstocks	Separate surge chambers.	Draft tube gate shafts act as surge shafts.
Tailwater elevations		
- Full generation load at minimum head	1460'	Both assumed at 880' MSL at this stage.
- Single generating unit, 60%, load, full head	1455'	
- Spillway passing 1:10,000 yr flood	1475'	910' MSL assumed

3.0 - PROJECT DESIGN DATA

3.1 - Topographical Data

The topography of the site is based on aerial survey mapping reduced to a scale of 1 inch:200 feet. Contours are at 5 feet intervals.

3.2 - Hydrological Data

The hydrological data is based on records taken over a period of 30 years. Streamflows and respective drainage areas are extrapolated and adjusted to give a representative pattern of flows at the damsite. Flows are shown on Tables _____ and _____.

3.3 - Meteorlogical Data

4.0 - DESIGN CRITERIA

4.1 - Civil Design

4.1.1 - Governing Codes and Standards

Where specific standards and design criteria are not covered in this criteria than the following codes and standards shall apply:

- American Concrete Institute "Building Code Requirements for Reinforced Concrete" (ACS 318-77).

4.1.2 - Design Loads

(1) Dead Loads:

Mass concrete	145 lbs/ft^3	(143 lbs/ft^3 when checking stability)
Reinforced concrete	150 lbs/ft^3	
Steel	490 lbs/ft^3	
Water	62.5 lbs/ft^3	
Silt - vertical	120 lbs/ft^3	
- horizontal	85 lbs/ft^3	
Backfill (all dams)		
- dry	115 lbs/ft^3)	
- saturated	130 lbs/ft^3)	- Provisional
- submerged	70 lbs/ft^3)	

(2) Backfill Loads

The lateral earth pressure against vertical faces of structures with horizontal backfill will be computed using the equivalent fluid pressures calculated from:

$$p = Kwh$$

where p = unit pressure, k = pressure coefficient, w = unit weight of fill, h = height of fill.

For structures free to deflect the pressure coefficient will be computed from Rankine's theory, which is:

$$k_A = \tan^2 (45-\emptyset/2)$$

where $\emptyset$ = angle of internal friction.

For structures restrained from using the pressure coefficient will be $K_o = 1 - \sin \emptyset$.

Coulomb's theory will be used for computing lateral earth pressures on wall surfaces with slopes flatter than 10 vertical: 1 horizontal or with sloping backfill steeper than 1 vertical: 4 horizontal.

Where verhicular traffic can run adjacent to the face a surcharge loading of 500 lbs/ft^3 should be applied.

(3) Wind Loads

(4) Snow Loads

(5) Powerhouse Floor Loads

Generator Hall	-	500 lbs/ft^2
Machine Shop	-	500 lbs/ft^2
Switchgear Room	-	300 lbs/ft^2
Service Bay	-	1000 lbs/ft^2
Control Room	-	200 lbs/ft^2
Transformer Gallery	-	300 lbs/ft^2
Offices and Stairs	-	100 lbs/ft^2

(6) Crane Loads

The following percentages shall apply to the powerhouse crane and the power intake gallery. The minimum deflection to span ratio of crane support beams shall be 1:1000.

Vertical impact	- 25% of static wheel load
Lateral load	- 10% of crane capacity, trolley, hook, and lifting beam distributed equally between rails.
Longitudinal load	- 10% of static wheel loads.

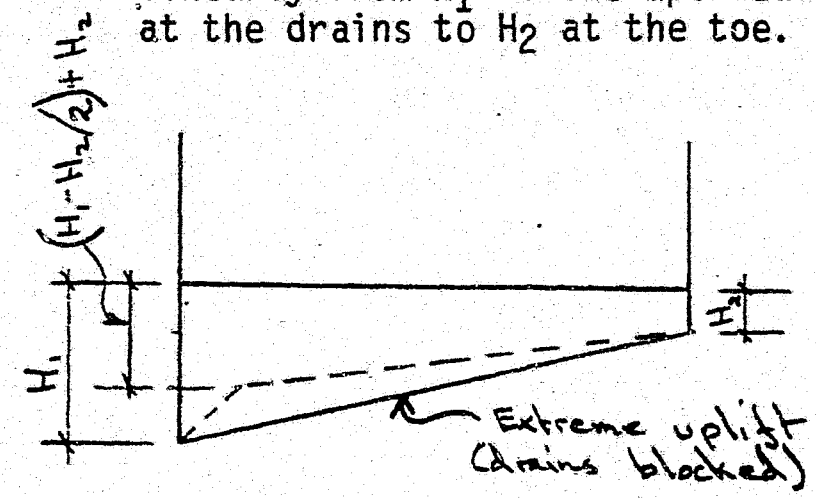
(7) Spillway Deck Loads

(8) Hydraulic Loads

All structures shall be designed for full lateral water pressures, where applicable, plus full hydrodynamic and uplift forces.

Uplift

(a) For water retaining concrete structures provided with drainage galleries and drail holes deep into the foundations, uplift shall be considered across the complete rock/concrete interface varying linearly from H_1 to the upstream heel to $(H_1-H_2)/2 + H_2$ at the drains to H_2 at the toe.



H_1 = static head upstream
H_2 = static head downstream

If uplift exceeds the bearing pressure (resulting from all forces except uplift) at the heel the uplift is to be redistributed inaccordance with USBR No. 19.

(b) Apron and chute slabs and slab walls against rock shall be designed against uplift resulting from sudden changes in water level.

Uplift from centrifugal forces shall be considered where contraction joints occur on concave floor of chutes.

Toe curve pressures on interior face of training walls at concave chute surfaces shall be calculated in accordance with Plate 21 of Hydraulic Design of Spillways EM 1110-2-1603 by U.S. Army Corps of Engineers.

Hydraulic loads due to earthquakes are given in the following section on seismic loads.

(9) Seismic Loads

Ground acceleration corresponding to maximum credible earthquake - 0.4 g.

Design earthquake return period - 100 yrs.

Ground acceleration corresponding to design earthquake - 0.2 g.

Arch Dam at Devil Canyon

The arch dam is to be checked under seismic loading by dynamic analysis based on trial load method and the ADSAS program developed by the Department of the Interior.

Arch dam system damping ratio - 0.10 of critical.

Acceleration response spectrum - See Figure 1. at Devil Canyon

Concrete Gravity Structures

For concrete gravity structures the horizontal force (V) due to earthquake ratio shall be:

V = 0.1 x ground acceleration x mass of structure.

Hydrodynamic Pressure

The hydrodynamic pressure due to horizontal earthquake on water retaining surfaces shall be computed using the theory of Westergard for the dynamic change in pressure:

$$P = a.\ 51.25\ \ hy\ \ lbs/ft^2$$

where h = total height of structure (ft)
y = depth below reservoir surface
a = ground acceleration

The distribution of pressure is parabolic and hence the total force and movement at a section y ft below water level are given by:

$$F = 2/3.\ P.y$$
$$M = 0.4.\ F.y$$

For hydrodynamic forces on earth structures see Section _____.

(10) Temperature

(11) Ice Loads

4.1.3 - Load Combinations

4.1.4 - Stability

Shear Friction Factor

The shear friction factor is given by shear friction factor = $\frac{CA + (V-U) \tan \phi}{H}$

C = cohesion
A = base area
V = total weight of structure
U = total vertical uplift force
Ø = angle of internal friction

4.1.5 - Stability Requirements

Concrete Gravity Structures

Load Conditions	Shear Friction Factor	Overturning	Flotation Factor	Compression Safety Factor
Normal	4 based on concrete 5 based on rock	Resultant within the Kern	1.5	3 based on concrete 4 based on rock
Unusual (Including 1:100 yr earthquake	"	Resultant within the Kern	1.3	2.5 based on concrete, 3.5 based on rock
Extreme	3.5 based on concrete, 4.5 based on rock	Max. allowable tension = 30 psi	1.3	2.5 based on concrete, 3.5 based on rock

Arch Dam

Compression Safety Factor, normal loads - 4
extreme - 1

Tension, normal loads - no tension
extreme - full tensile strength of concrete

4.1.6 - Material Properties

4.2 - Hydraulic Design

4.2.1 - Reservoir Levels

Reservoir levels are tentative at this stage and will change with optimization of the maximum pool level, and with the determination of the live storage.

Operating Levels	Watana	Devil Canyon
Normal maximum	2200' MSL	1445' MSL
Normal minimum	2050' MSL	
Flood Levels		
1:10,00 yr	2205' MSL	1450' MSL
p.m.f.	2225' MSL max.	1455' MSL

4.2.2 - Freeboard

Allowance for wave height and run up - 6 feet
Allowance for flood discharge above normal maximum operating level - 5 feet

Area and Storage

	Watana	Devil Canyon
Area at normal maximum operating level	40,000 acres	21,000 acres
Live storage	4.6 x 10^6 acre/ft	0.7 x 10^6 acre/ft
Full storage	10 x 10^6 acre/ft	1.1 x 10^6 acre/ft

4.2.3 - Tailwater

Water Levels	Watana	Devil Canyon
1:10,00 yr flood	1475' MSL	910' MSL
1 unit operating	1455' MSL)	880' MSL
Average tailwater level	1460' MSL)	(assumed)

4.2.4 - Flows

(See Figure 4, flood volume/frequency curves)

	Watana	Devil Canyon
Mean annual inflow	7,860 cfs	8,960 cfs
1:50 yr flood peak inflow		
1:500 yr flood peak inflow	116,000 cfs	
1:1000 yr flood peak inflow	155,000 cfs	135,000 cfs*
Probable maximum flood	235,000 cfs	270,000 cfs*
Routed 1:10,00 flood peak	115,000 cfs	135,000 cfs

Minimum downstream releases

* After routing through Watana

4.2.5 - Criteria

4.2.5.1 - Spillways

Capacity

- Pass p.m.f. while maintaining the integrity of the main water retaining structures. Local damage to these structures is allowable.

- Pass routed 1:10,000 yr flood with no damage. A main service spillway for general operation with a secondary spillway operated only for short duration is acceptable.

Chute

- Maximum velocity 150 fps without aeration.

Energy Dissipation

- Minimum radius of flip bucket > 7 x depth of design flow.

- Max energy dissipated by stilling basin - 45,000 hp/ft width.

4.2.5.2 - Power Facilities

4.3 - Geotechnical Criteria

4.3.1 - Main Dam

(1) Dimensions

Crest elevation	- 2225' MSL
Maximum height above lowest foundatin	- 900' approx.
Crest width	- 80'
Upstream slope	- 1:2.75*
Downstream slope	- 1:2*

(2) Design Criteria

The dam will be checked for normal static loading conditions such as end of construction, normal operating cofferdam and drawdown condition.

The dam will be designed to withstand the maximum credible earthquake.

4.3.2 - Excavation

Rock cuts at structures	- slope 10V:1H (overall)
Permanent rock cuts	- slope 4V:1H (overall)
Permanent cuts in overburden	- slope 1V:2H (overall)

4.4 - Mechanical Criteria

4.4.1 - Power Intake

(1) Trashracks

	Watana	Devil Canyon
Type	flat	flat
Maximum gross velocity through racks	4 f.p.s.	4 f.p.s.
Handling	Gantry crane	Gantry crane
Number	4 sets	4 sets

(2) Gates

	Watana	Devil Canyon
Type	Fixed wheel vertical	Fixed wheel vertical
Handling	Indiviudal hoist	Individual hoist
Number	4	4

(3) Bulkhead Gate

	Watana	Devil Canyon
Type	Bulkhead	Bulkhead
Handling	Gantry crane	Gantry crane
Number	one set	one set

4.4.2 - Powerhouse

(1) Turbines

	Watana	Devil Canyon
Type	Vertical francis	Vertical francis
Number	4	4
Head - maximum	715 ft*	554 ft*
- rated	680 ft*	550 ft*
- minimum	565 ft*	550 ft*
Rated discharge	5300 cfs	3630 cfs
Rated output (full gate)	370,000 hp**	205,000 hp
Best gate output	85% full gate	85% full gate
Efficiencies - full gate	90%	90%
- best gate	93.5%	93.5%

* To be revised after determination of reservoir level and live storage.

** Likely to change to smaller units.

(2) Powerhouse Crane

Type - overhead traveling
Number - 2
Capacity - sufficient to lift generator rotor and follower.

(3) Draft Tube Gates

Bulkhead gates handled by fixed overhead hoist.

(4) Tailrace Outlet

Stoplogs handled by mobile crane.

4.4.3 - Spillway

(1) Gates

- Number ..... to suit design flood
- Size ..... maximum size = 45 ft wide x 65 ft high
- Type ..... fixed wheel vertical lift, heated or winter operation
- Hoisting ..... wire rope hoist on tower and bridge structure

(2) Stoplogs

One set handled by mobile crane and follower.

4.4.4 - Outlet Works and Low Level Outlets (Watana only)

(1) Gates

- Either fixed wheel vertical lift, radial or slide gates; operated by hydraulic hoist.
- Gate head and width to be within current precedent.
- Emergency gate to be provided upstream of control gate.

(2) Valves

- Fixed cone full discharge valves with ring follower gate upstream for emergency closure.

(3) Stoplogs

- One set stoplog guides at upstream entrance of tunnel.

(4) Trashracks

- Located at upstream entrance of tunnel.

4.4.5 - Diversion

(1) Closure Gate

- Fixed wheel vertical lift gates handled by gantry crane or fixed wheel.

(2) Control Gate

- As per gates by low level outlet and outlet works.

(3) Stoplogs

- Where required, handled by mobile crane.

4.5 - Electrical Criteria

4.5.1 - Generators

	Watana	Devil Canyon
Number	4	4
Type	Vertical synchronous	Vertical synchronous
Rating	310 MVA**	165 MVA
Power factor	0.9	0.9
Efficiency	98%	98%

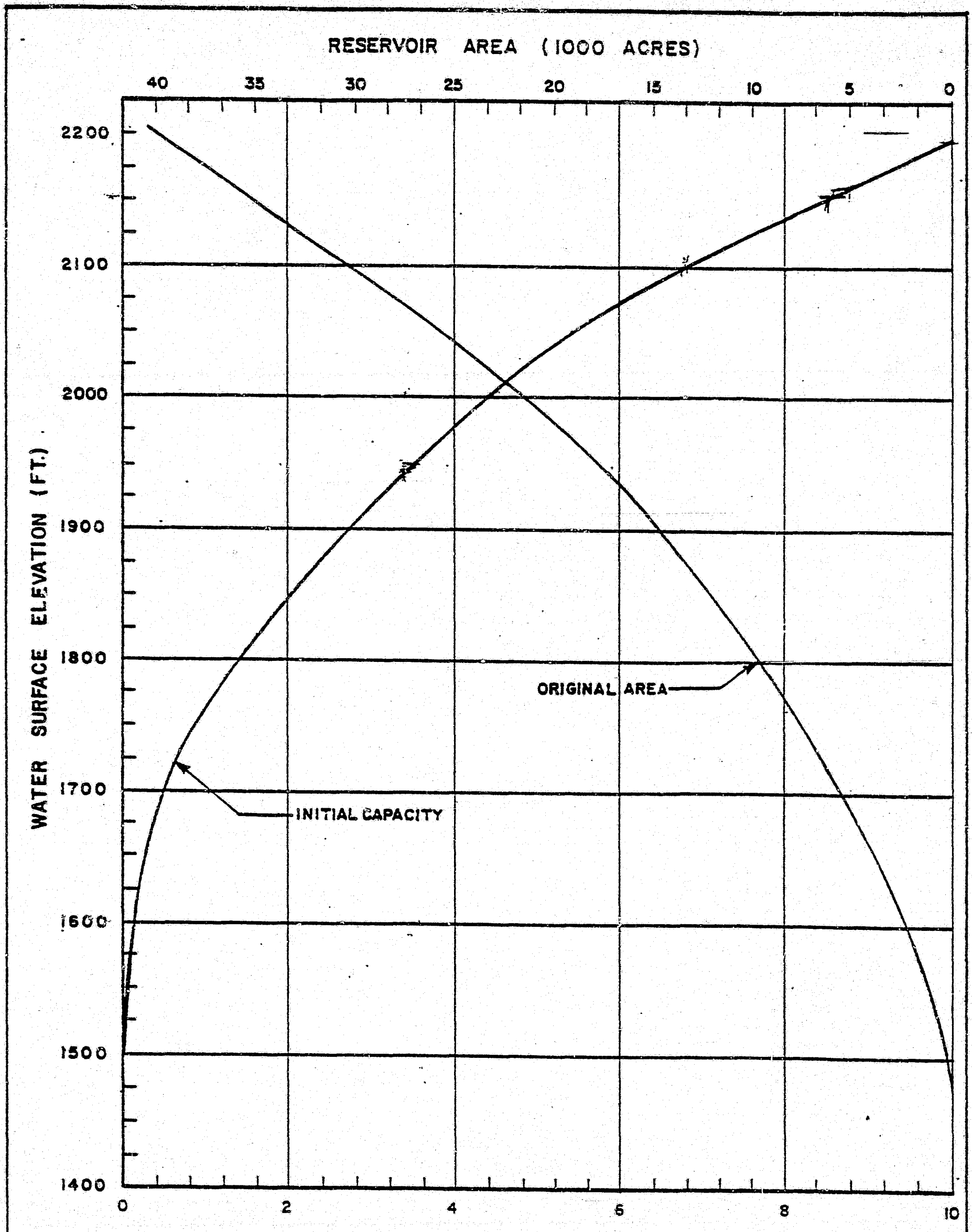
Transformers

	Watana	Devil Canyon
Number	4	4
Rating	300 MVA**	165 ~~300~~ MVA
Voltage	13.8 kV - 345 KV	13.8 kV - 345 kV
Phases	3	3

Switchyard

Type - Conventional outdoor switchyard.

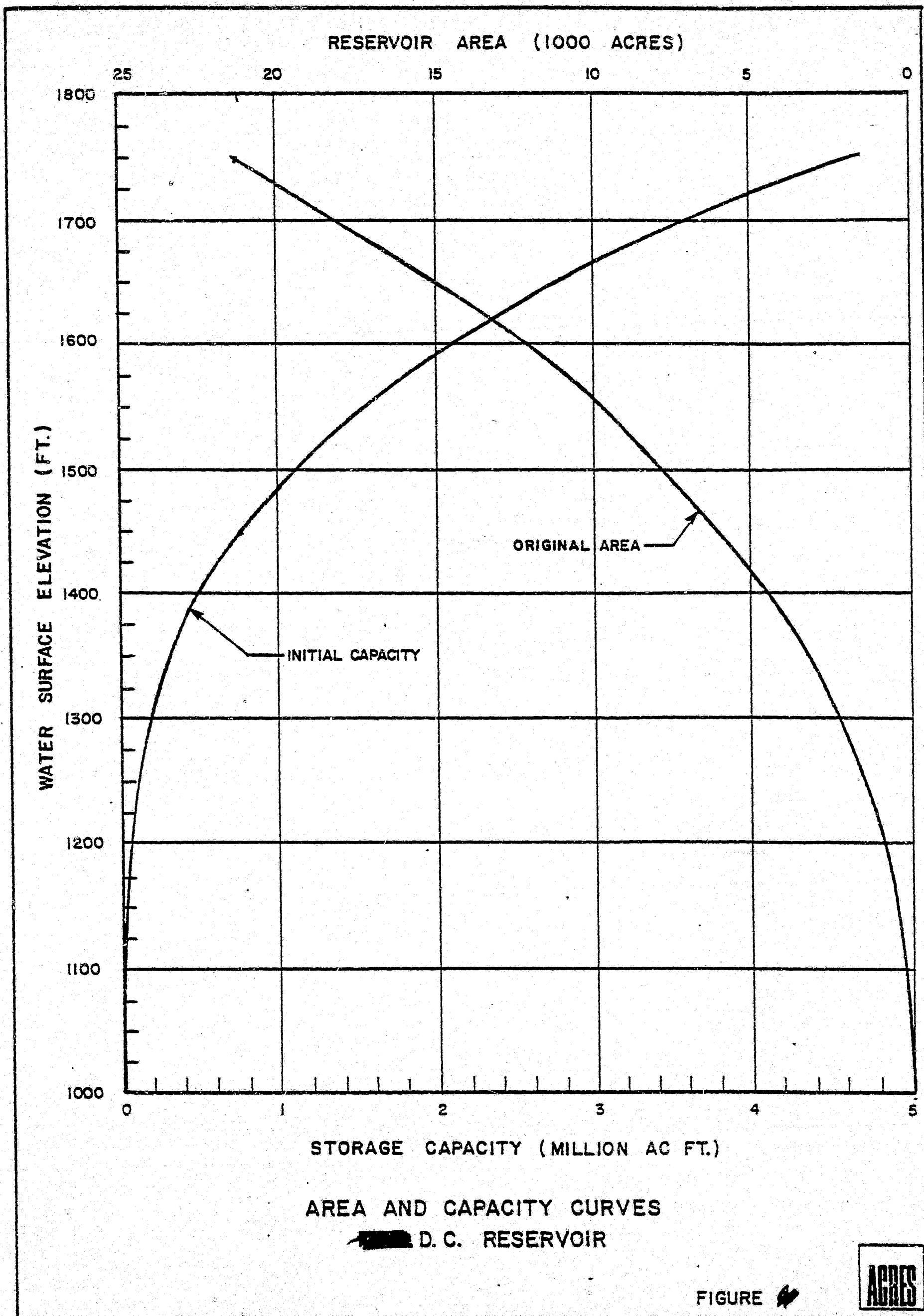
** Likely to change to smaller units.



AREA AND CAPACITY CURVES
WATANA RESERVOIR

FIGURE 4

ACRES



AREA AND CAPACITY CURVES

[redacted] D. C. RESERVOIR

FIGURE [redacted]

ACRES